MODELING OF "GROOVE" ROLLING DEFECT ON INTERNAL SURFACE OF PIPES AT LENGTHWISE ROLLING

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Abstract

The research has been conducted in pipe forming at rolling off by lengthwise rolling mill with stub mandrel; the patterns of change in dimensionless parameters were determined, which characterize deformation in side angle depending on http://www.multitran.ru/c/m.exe?t=424995_2_1elongation ratio. The model of formation of lengthwise groove on internal surface of pipes has been proposed.

On pipe-rolling mill PRM – 140 of Open Joint-Stock Company «Sinarsky Pipe Works» pipes are rolled from carbon and alloy superduty steels: drill pipes, casting pipes, pipes for power plant engineering industry and others in diameter from 73 to 168 mm with wall thickness from 5 to 23 mm. An outstanding feature of pipes production on PRM – 140 is limitation on deformation of pipes in lengthwise rolling mills (LRM), which are the part of the mill and are spaced some distance apart. Elongation ratio on LRM-1 is within the limits of 16÷1,5, and on LRM-2 – 1,07÷1,15 [1]. Application of heavy reductions leads to heavy reductions on internal surface of a pipe. So far there is no unanimous view on the reasons for the emergence of this defect and no objective and accurate analysis has been made in this connection. Recommendations on prevention of lengthwise grooves emergence are ambiguous and controversial. This study proposes the model of lengthwise grooves emergence and provides the research of pipe forming at lengthwise rolling with stub mandrel.

The study of pipe forming was conducted using software solution «DEFORM – 3D». Following the recommendations of the original programmers and taking into account practical data about pipes rolling on the mill LRM [3] initial conditions included data about pipe temperature $\Theta = 1200^{\circ}C$, roll and mandrel temperature $\Theta = 150^{\circ}C$, air temperature $\Theta = 20^{\circ}C$. Heat transfer from stock material to the tool was determined by heat transfer coefficient $\alpha = 5\dfrac{W}{m^2K}$. In a solid model discrimination of deformation zone was done with the help of end elements in the shape of tetrahedron. Their quantity amounted to 350000. On the surface of the tool border-line conditions were determined in the following way: normal velocity of metal particles was $V_{n|S_S} = 0$; friction law was set by Zibel $\tau_{|S_S} = \psi\tau_S$. Friction forces on roll value was assumed to be $\psi = 0{,}7$, and on the mandrel it was $\psi = 0{,}2$. Front and bottom ends of the pipe being rolled are free from the load, consequently, at inlet and outlet sections of deformation zone normal stress amounts to zero: $\sigma_{XX|S_f} = 0$, on free surface at side angle $\sigma_{n|S_f} = 0$. Rolls spinning speed on LRM-1 and LRM-2 is assumed to be equal to 125 rpm. Diameter of body of roll on LRM $D_b = 590$ mm. The gap between rolls flanges $\Delta = 4$ mm. Diameter of stock material (shell), which is manufactured on piercing mill, during computational experiment is assumed to be equal in all the experiments $D_s = 166$, and shell wall thickness is different S_s=10,11,12,13 и 14 mm. Diameter and pipe wall thickness in all the experiments after rolling on LRM-1 were $D_{LRM-1} = 160$ mm and $S_{LRM-1} = 7$ mm, after LRM-2 $D_{LRM-2} = 156$ и $S_{LRM-2} = 5{,}6$. Mandrel diameter $D_{man1} = 146$ mm and $D_{man2} = 145$ mm. Therefore, elongation ratio at the first pass was 1,46; 1,6; 1,73; 1,86; 1,99. At the second pass elongation ratio was constant in all the experiments and was 1,10. The study of metal forming was conducted for two variants of work roll pass design: circular and hexagonal. When modeling of rolling process operating roll pass designs on PRM-140 were applied. side angle for both designs was $\varphi = 30^{\circ}$. The study of metal forming consisted in determination of the principles of elongation ratio influence on dimensionless parameters, which characterize pipe deformation at side angle $\dfrac{S_{sa}}{S_{apex}}$; $\dfrac{\delta}{S_{sa}}$; $\dfrac{C}{S_{sa}}$. Here S_{sa} - pipe wall thickness at side angle; S_{apex} - pipe wall thickness at the apex of the pass; δ - the value of gap between the mandrel and on internal surface of a pipe; C- the length of free surface of mandrel (fig.1).

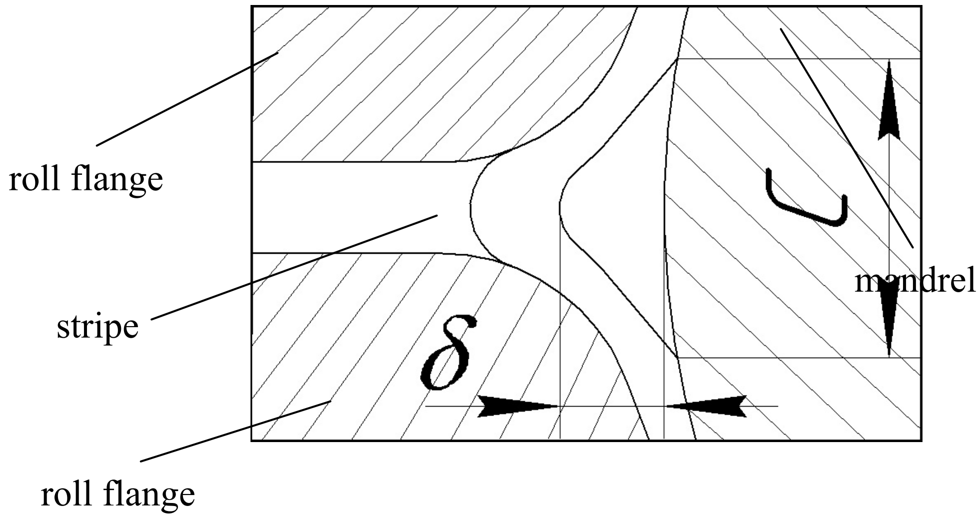


Fig.1.Scheme for δ and C parameters determination

In table 1 there are the results of calculations having been done for metal forming at side angle when pipe rolling during the first pass (LRM-1) using hexagonal and circular pass designs. Based on the data from table 1, the graphs on fig.2 have been constructed.

From Fig. 2 and table 1 it is clear that as elongation ratio λ growths, increase in wall thickness at side angle occurs, which is evidenced by growing ratio $\frac{S_{sa}}{S_{apex}}$. It should be noted that at rolling with hexagonal pass design rolls, increase in wall thickness at side angle develops less intensively than at rolling with circular pass design rolls. Fig. 2 and table 1 also demonstrate that as as elongation ratio λ growths, ratios $\frac{\delta}{S_{sa}}$ and $\frac{C}{S_{sa}}$ decrease, which indicates the decrease in the gap between the pipe and the mandrel as λ increases.

The reported results of the research in metal forming allow to explain the reasons of lengthwise grooves forming lengthwise grooves formation.

Fig. 3 shows the scheme of pipe wall reduction at the second pass (LRM-2). It can be seen that at the initial instant there are adverse conditions on the mandrel for oil retention on contact area. Hence sticking of metal on the mandrel and lengthwise grooves forming can occur.

Table 1

The results of calculation of dimensionless parameters, characterizing metal forming at rolling on rolling mills в LRM-1

λ	Hexagonal pass designs			Circular pass designs		
	$\frac{S_{sa}}{S_{apex}}$	$\frac{\delta}{S_{sa}}$	$\frac{C}{S_{sa}}$	$\frac{S_{sa}}{S_{apex}}$	$\frac{\delta}{S_{sa}}$	$\frac{C}{S_{sa}}$
1,46	1,31	0,13	3,36	1,37	0,19	3,02
1,60	1,39	0,11	2,44	1,47	0,13	2,63
1,73	1,48	0,09	2,03	1,56	0,11	1,68
1,86	1,57	0,08	1,83	1,63	0,10	1,56
1,99	1,73	0,05	0,47	1,85	0,06	0,84

Furthermore, at rolling of pipes with big ratio $\frac{S_{sa}}{S_{apex}}$ on LRM-2 in the areas 1 and 2 (fig. 3a) clamps are produced (fig. 3b). Then at plugging on three-high reeling mill these clamps are reeled, and being treated on stretch reducing mill they transform into lengthwise grooves. Consequently, the bigger the ratio $\frac{S_{sa}}{S_{apex}}$ is, the bigger is the possibility of clamps and lengthwise grooves formation. Therefore, when rolling with circular pass designs, lengthwise grooves formation on internal surface of pipes is more likely to occur than when rolling with hexagonal pass designs.

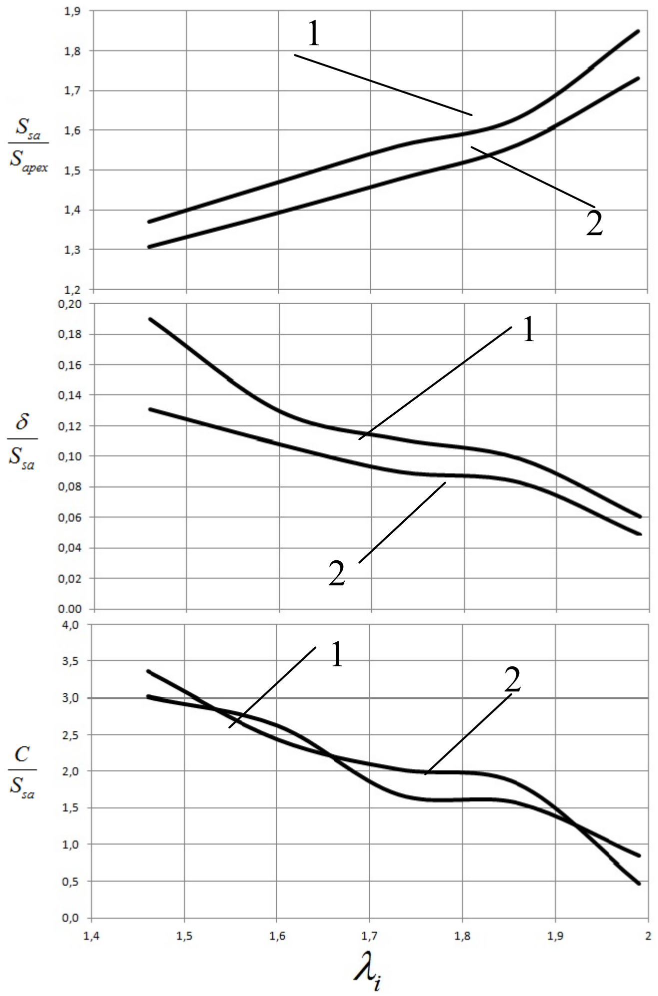
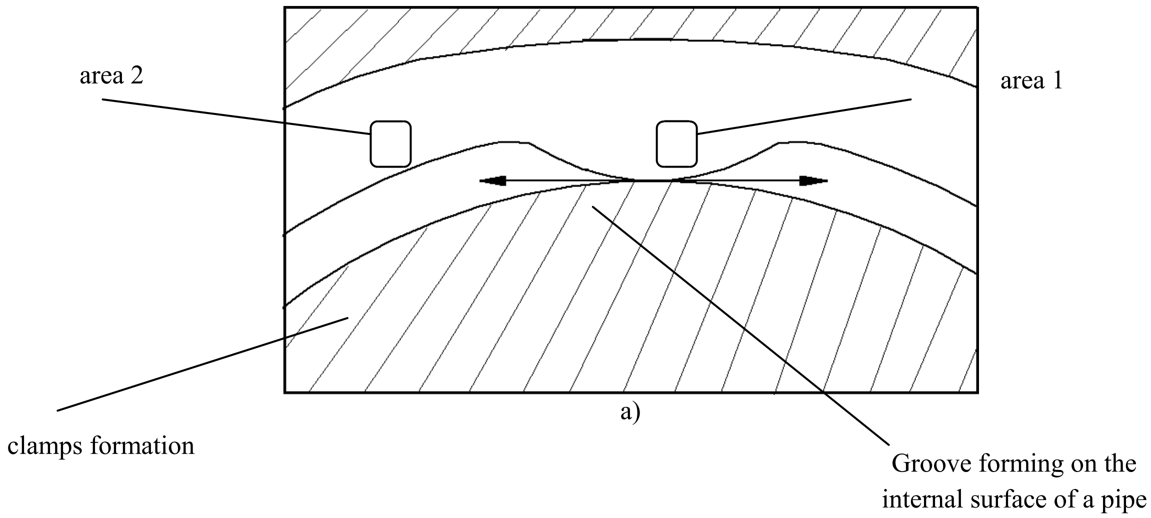
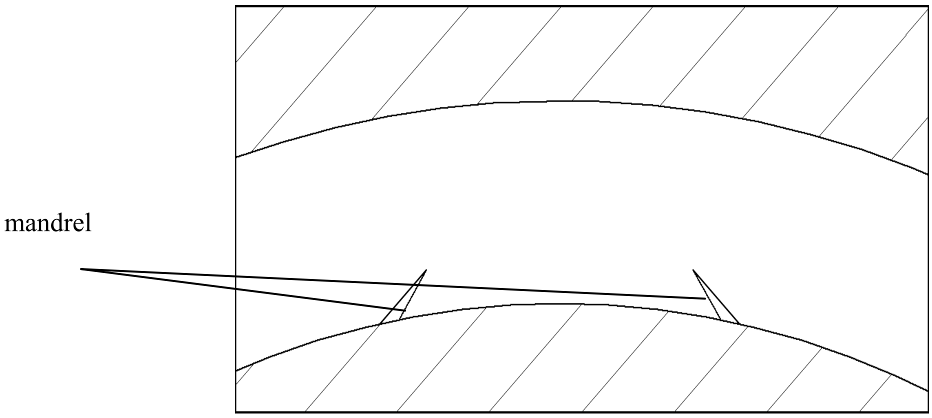


Fig. 2 Graphs of dependence of dimensionless parameters, characterizing the pipe deformation at side angle on elongation ratio: 1- circular pass design; 2 - hexagonal pass design.



a)



б)

Fig. 3 Scheme of plugging on the mandrel at the second pass (LRM2)

The study proposes the model of lengthwise grooves formation on internal surface of pipes, produced on PRM – 140 on LRM mills. The study of pipe forming was conducted using software solution «DEFORM – 3D», the patterns of change in dimensionless parameters $\frac{S_{sa}}{S_{apex}}$, $\frac{\delta}{S_{sa}}$, $\frac{C}{S_{sa}}$ were determined depending on the elongation ratio λ on the first stand of elongator. It has been shown that when using hexagonal pass designs in comparison with circular pass designs the proportion of displaced volume on the pipe axis is greater, the value $\frac{S_{sa}}{S_{apex}}$ is lower; thereby, the risk of «lengthwise groove» defect forming is reduced.

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